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Insight into cumulative intra-guild and intra-specific depredation among sharks

by

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Résumé. – Description du phénomène de déprédation cumulative inter- et intra-spécifique chez les requins.

La prédation intra-guilde (PIG), la déprédation de requins pris sur des hameçons et le cannibalisme ont déjà été décrits pour le requin tigre *Galeocerdo cuvier* et le requin bouledogue *Carcharhinus leucas*, essentiellement à propos d'animaux de grande taille se nourrissant sur de plus petits requins. Dans cette note, nous rapportons deux cas d'étude dans l'océan Indien et l'océan Pacifique qui montrent une déprédation cumulative inter et intra-spécifique de ces deux espèces, impliquant de la déprédation entre gros adultes sur les derniers stades. Ces informations renforcent l'hypothèse que la PIG et le cannibalisme entre gros animaux existent potentiellement à l'état naturel et interfèrent avec les dynamiques proies-prédateurs en milieu marin tropical.

Key words. – Carcharhinidae - *Galeocerdo cuvier* - *Carcharhinus leucas* – Indian Ocean – Pacific Ocean - Inter-specific depredation - Trophic interaction.

Lethal interactions among large vertebrate predators have attracted interest of researchers for a long time because of ecological and conservation issues. In the marine environments, predation can be defined as the act of killing and eating another marine organism. It can occur as inter-specific predation between different species with a particular case of intra-guild predation (IGP) (Polis *et al*., 1989) between animals of close taxonomic groups that are competitors, or as intra-specific predation (Polis, 1981), i.e cannibalism (Fox, 1975). The concept of predation implies that prey are free-ranging animals. When predation occurs on animals captured on hooks, it is described as depredation, which can be defined as "the partial or complete removal of hooked fish or bait from fishing gear" (Donoghue *et al*., 2003). This phenomenon was extensively described regarding toothed whales, which significantly impact professional fisheries by depredating hooked fish, as easily available prey. Sharks are also reported for depredation on hooked teleosts (Gilman *et al*., 2008), and sometimes on Chondrichthyes, i.e. hooked sharks (McNeil *et al*., 2009). However, as far as we know, cumulative depredation of sharks by sharks on a single hook has never been documented.

IGP has however been documented for the tiger shark *Galeocerdo cuvier* (Péron & Lesueur, 1822), and bull shark *Carcharhinus leucas* (Müller & Henle, 1839) (Compagno, 1984; Cliff and Dudley, 1991). These sharks are notorious for cannibalism. For example Snelson *et al*. (1984) documented a 162 cm TL bull shark *C. leucas* consuming a younger conspecific (around 80 cm TL). However, no evidence has been reported for cannibalism among these species involving a large adult animal predating on another large similar sized conspecific.

Here we report two case studies that involve similar processes occurring in different oceans and involving different species of sharks. These case studies are based on successive inter-and intra-specific depredation of sharks by sharks on a single hook, including very large animals at the final stage.

MATERIAL AND METHODS

In both locations, the fishing lines were composed of a "drumline", i.e. baited hooks set on a wire attached to a line and a float. Firstly, in the Seychelles, a two-day fishing session (May 1998) was conducted with one drumline set and baited with small pelagic fishes (great barracuda, *Sphyraena barracuda*, and stripped bonito, *Sarda orientalis*) in the channel between d'Arros and Saint-Joseph islands (5°25'S; 53°18'E). Secondly, in the remote northern-west barrier reef of New Caledonia over 100 km from the mainland (19°38'S; 163°32'E), a six-day fishing session (March 2010) was conducted with two to eight drumlines deployed and baited with rotten yellowfin tuna heads (*Thunnus albacares*). Lines were soaked for 36 hours (Petite Pass), eight hours (Estree Pass) and 12 hours (close to Belep Island) respectively, with checks on the lines done at two hourly intervals. Sharks captured were restrained in a harness and were tape measured. When only heads of the animals were available, Total Length (TL) was estimated based on the relationship between bite circumferences (jaw width measured on the shark) and TL provided by Lowry *et al*. (2009).

RESULTS

In the Seychelles, an estimated 2 m TL tiger shark (*G. cuvier*) was caught on the line during the first night and left in the water. Approximately 10 h later (around 4 pm), a 4 m TL tiger shark was found caught on the same line, after ingesting its smaller conspecific (Fig. 1A). The same day, the drumline was reset and an estimated 1 m TL grey reef shark (*Carcharhinus amblyrhynchos*) was caught at approximately 8 pm and left on the line (Fig. 1B). After two hours, an estimated 2 m TL bull shark (*C. leucas*) was hooked after ingesting the grey reef shark (Fig. 1C). The line remained in the water for the night and was retrieved on the next morning (at around 6 am). The bull shark had also been consumed by a much

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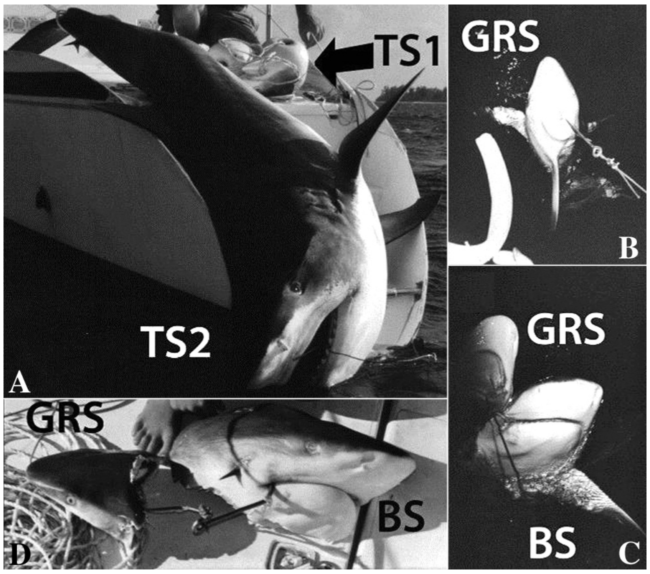


Figure 1 - Photographic evidence from Seychelles. **A**: Intra-specific depredation of a ~2 m TL tiger shark *Galeocerdo cuvier* (TS1) by a 4 m TL conspecific (TS2); **B**: Inter-specific depredation based on the catch of a ~1≈m TL grey reef shark *Carcharhinus amblyrhynchos* (GRS), that was almost entirely consumed by **C**: ~2 m TL bullshark *C. leucas* (BS), which was (**D**) itself depredated, probably by a large tiger shark (Photo courtesy of JBG).

larger shark, probably a tiger shark as suggested by the bite features (JBG, pers. obs.) (Fig. 1D).

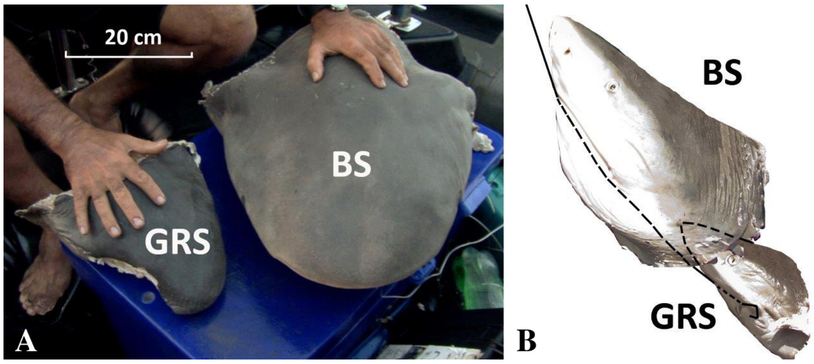
In New Caledonia, four adult tiger sharks and two adult male bull sharks were caught and released during the two first fishing sessions. However, on the last check of a drumline in Estree Pass, the head of an adult grey reef shark (*Carcharhinus amblyrhynchos*) (attached to the hook) was found inside the mouth of a much larger head of an adult bull shark. The bull shark had ingested the grey shark caught on the hook, and in turn was then consumed by a larger shark (Fig. 2). The width of the main bite behind its head was ~44 cm (Fig. 2A). Based on formula for assessing TL from jaw width provided by Lowry *et al.* (2009), only three shark species commonly encountered in coastal waters could inflict such a bite. This includes a white shark *Carcharodon carcharias* of ~2.6 m TL, bull shark of ~2.8 m TL or tiger shark of ~3.1 m TL. The three species can be found in New Caledonia during this time of the year. However, extensive fishing efforts pre- and post-event did not reveal tiger or white sharks in the area of the Estree Pass. Without being fully ascertained, we consider that the most probable hypothesis relies on an intra-specific predation by a bull shark of similar size, which is consistent with the gape of one of the adult bull sharks caught on the other lines in close proximity (several 100 m). In support, Springer (1963) yet reported that a fishing crew working off the northeast coast of South America had good success taking bull sharks using fresh shark bait. Consumption of large adult bull sharks by similar sized conspecifics was also witnessed by one of the authors on the northeastern Australian coast (JW, pers. obs.).

DISCUSSION

Both case studies allowed us to document a phenomenon of “double” or cumulative depredation of shark by shark on a single hook, involving tiger shark and bull shark. Without fully demonstrating them, we however suggest the available evidence supports the hypotheses that the final depredator was a large tiger shark in the Indian Ocean and a large bull shark in the Pacific Ocean. Indeed, our data suggest depredation from the same species (tiger *vs* tiger) and then the same guild (tiger *vs* bull) in the Seychelles case and probably from the same species (bull *vs* bull) in the New Caledonia case. Nonetheless, depredation cannot be confounded with predation on free ranging animals. However, in the “shark-eat-shark” episodes documented by Vorenberg (1962), bull sharks were induced to perform a series of “feeding frenzies”, in which one or more sharks were consumed after being injured in fights for food by an agitated group of sharks. The cases of intra-specific depredation that we are here describing suggest that cannibalism among large adult sharks is possible in the wild for both species. As far as we know and unless Vorenberg’s experiment did also involve adults eating other similar sized conspecifics (which is not detailed in the study), we have documented the first evidence of potential cannibalism among adult bull sharks in the wild, probably facilitated by “feeding frenzies”.

This enlightenment of potential cannibalism among adult animals appears interesting as the function of cannibalism in sharks needs further exploration when considering their role in ecosystems. Numerical models of the trophic pathways in the central north Pacific Ocean demonstrate that increasing the amount of theoretical cannibalism for sharks, thus removing them from the system, produced strong reactions throughout the food web that were not seen when actual diet data were used (Kitchell *et al.*, 2002). Still from a theoretical point of view, Sun *et al.* (2009) showed that predator cannibalism may have significant influence on the formation of spatial patterns in predator-prey systems and the understanding of the “Turing” concept. Mutual interference between predators is one of the most convincing mechanisms for the spontaneous generation of patchiness through predator-prey trophic interaction in

Figure 2. - Photographic evidence from New Caledonia. (**A**) Inter-specific depredation of a ~1.2 m TL grey reef shark *C. amblyrhynchos* (GRS) that was depredated by a ~2.6 m TL bullshark *C. leucas* (BS), which was itself almost entirely consumed probably by a larger conspecific after (**B**) consuming the grey reef shark (Photos courtesy of B. Claude).



a homogeneous environment. It brings instability once the functional response does not depend only on prey density (Alonso *et al.,* 2002). This capacity of some large species of reef top predator to cannibalize conspecifics of a similar size should then be better addressed in the field and in the context of better understanding the natural functioning of tropical reef ecosystems.

From a longline fishery point of view, depredation of shark on sharks demonstrates a low level of interaction, corresponding roughly to 1-6% of individual shark species catch (MacNeil *et al.*, 2009) or to ~7% of elasmobranch catch as a group (Romanov *et al.*, 2008). In addition, bull shark and, at a less extent, tiger shark, are not considered as "real" pelagic species with a high vulnerability to longlining. Thus the cumulative shark depredation that we are describing here does not represent an issue in terms of a potential worsening factor for mitigating the discard and losses amongst voluntary (through shark fisheries) and unvoluntary (through shark by-catch) capture of sharks through longlining. Nonetheless, while our results are not directly comparable to longlining, reduction of soaking time may be an important factor to consider as it is positively correlated with depredation (Gilman *et al.*, 2008).

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